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Case report

The value of radiocarbon analysis in determining the forensic interest of human skeletal remains found in unusual circumstances

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ABSTRACT

The case under analysis refers to the remains of a young adult female found in a shallow grave during the construction work of a hospital in Northern Portugal. The forensic interest of the finding could not be ruled out since distinguishing features pointing to an archaeological grave were lacking. For example, absence of archaeological artefacts could not establish its forensic significance with certainty, together with the absence of modern objects, such as remnants of clothing or personal objects. In addition, although the remains were badly preserved, the condition may not have resulted from a long post-depositional period, but instead could be explained by the geology of the site and the presence of plant roots. The radiocarbon analysis of the remains was meant to establish the death of the individual to before or after the mid-1950s, from comparison with bomb-curve content values. A value of 0.9789 ± 0.0044 for $F^{14}C$ (pmC = $97.19 \pm 0.44\%$ Modern or $\Delta^{14}C = -28.1 \pm 4.4‰$) was obtained, which placed the death of the individual in the pre-mod-1950s period. This report illustrates the use of radiocarbon analysis in establishing whether the human remains are contemporary or not and describes evidence for what appears to be an historic clandestine grave.

1. Introduction

In forensic anthropology, an initial step during the post-mortem examination of human remains is to determine whether they are of forensic interest or of some antiquity. In cases of completely skeletonised remains it is often difficult, if not impossible, to determine from their state of preservation solely whether they have a few years, decades or centuries. For example, according to the literature, when decomposition occurs on the ground surface, complete skeletonization occurs within around 3 years of death[1] and very broad estimates of time since death can be made from bone destruction,[2] but these cannot discriminate a century-old from a decade-old skeleton. In addition, when cadavers are buried, the process of underground decomposition is insufficiently known to provide any guidelines about the velocity of soft tissue and particularly bone decay so that the antiquity of remains cannot be determined from morphological changes. When bones retain soft tissue, grease or odour, or when personal objects are found in close association with the skeleton, the forensic significance of the remains is often relatively straightforward. Consequently, dry clean bones and lack of associative evidence makes for a hard case of determining the forensic relevance of the remains.

Forensic relevance refers to remains needing investigation, namely with respect to the circumstances of death and the identification of the individual. In a criminal investigation, if the crime of homicide has prescribed, the case usually is no longer of forensic interest (in Portugal a crime has prescribed if more than 15 years has elapsed). However, some civil cases may require further investigation with respect to identification. Analysis of radiocarbon content in bone and careful comparison with atmospheric radiocarbon bomb-curve values can aid in determining the forensic relevance by discriminating human remains from individuals who died before 1950 from those who were alive after that date[3–8]

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(Geyh, 2001; Taylor et al., 1989; Ubelaker, 2001; Ubelaker and Buchhoz, 2006; Ubelaker and Houck, 2002; Wild et al., 2000). Although establishing the date of death later than the mid-1950s may not ascertain the forensic interest of the finding, for example due to criminal injunction within the last 50 years, a pre-mid-1950s dating can usually rule out any forensic significance. The unusual circumstances of the discovery of a shallow grave during the construction work of a hospital in northern Portugal required a first assessment of the forensic significance of the human remains. In light of the difficulties encountered, the use of alternative and more reliable approaches to estimate time elapsed since death became critical. In particular, lack of distinguishing features which could point the grave to an historic or modern context justified the use of a radiometric dating method based on the radiocarbon content of bone. This case report describes how radiocarbon analysis was paramount in determining the forensic relevance of the remains.

2. Case history

In 2009, the Portuguese criminal police submitted human remains to the National Institute of Legal Medicine, in Porto, for analysis by a forensic anthropologist. The remains had been found buried at the construction site of a Hospital in the northern city of Braga, Portugal. The grave was found by an archaeologist who was supervising the construction site for archaeological evidence, and was initially detected when cranial fragments were brought to the surface by a wheel crawler caterpillar. Since the construction site did not produce archaeological evidence in the immediate vicinity of the skeleton, the proper authorities were called upon. The excavation of the grave was undertaken by a field team of the Portuguese criminal police, who carefully documented the finding and collected all physical and contextual evidence. The excavation revealed an almost complete articulated skeleton at about 50 cm deep, from what appeared to be a single burial, but no grave pit was identified. There were no artefacts, objects, remnants of fabric, metal or of any other material associated with the skeleton and burial.

The analysis of the remains revealed a fairly complete but poorly preserved skeleton, belonging to one single individual (Fig. 1). Osteological indicators of the innominate suggested female sex. Lack of degenerative changes in the skeleton and dentition was indicative of a young adult. State of fusion of secondary centres of ossification in the sacrum,[9] in the cervical column[10] and completed dental maturation[11] indicated that age at death ranged from 16 to 24 years. Stature estimated from long bone length[12] revealed an adult female, who stood at about 147–165 cm tall. Pathological conditions ante-mortem included osteolithic lesions in the thoracic vertebra consistent with Schmorl's nodules, and marked enamel defects in the anterior dentition indicative of a single macroscopic linear enamel hypoplasia (Fig. 2). Among individual dental features, the third molar recovered showed a distinctive Carabelli's cusp. No other individual skeletal features were identified and no evidence of peri-mortem trauma was detected either.

During the examination by the forensic anthropologist, significant taphonomical changes to the skeleton were noted. These included extensive dissolution and destruction of periosteal and cortical bone, exposing the underlying trabecular bone, particularly at the epiphyses. All bones were dark brown in color and covered with dark soil and plant roots, which occasionally grew through some of the bones, particularly the vertebra. Consequently, root etching is frequent as well as bone flacking and longitudinal cracking (Fig. 3).

These taphonomical changes are consistent with a burial environment which promoted dissolution of the bone. Photos and information collected on site, and data from the post-mortem

Fig. 1. Overview of the skeleton during the post-mortem examination. Note the poor state of preservation.

Fig. 2. Linear enamel defect on upper left canine and upper lateral incisor.

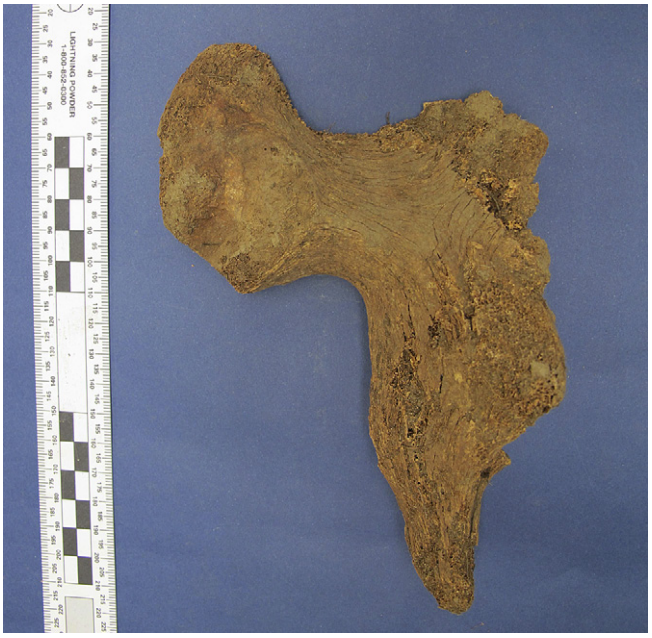

Fig. 3. Cortical cracking and weathering on the right inominate.

examination permitted the general observation that the most likely explanation for the state of preservation of the skeletal remains is an acidic environment. This acidity has two main origins: 1) the soil in which the remains where buried results from the break down of granite rock, a typically acid substrate; and 2) the grave's surrounding soil was particularly rich in and filled with plant roots. These plant organs produce acid secretions as they grow around and through the remains. In such circumstances it is difficult to evaluate whether the relatively poor state of preservation is the result of a very long post-depositional period or the result of the harsh burial conditions.

3. Forensic interest and radiocarbon analysis

The difficulty with this case is that there were no obvious and definite features which could have pointed this grave and skeleton to either an historic/prehistoric period or to an actual forensic case. The fact that there was no evidence for modern artefacts, such as remnants of clothing or personal objects, like a watch or wallet, together with the extensive post-mortem change, the presence of severe enamel hypoplasias and the possibility that the position of the skeleton can be interpreted as if the cadaver was laid in a funerary ritual, all lead and are suggestive of an archaeological finding, with no forensic interest. On the other hand, neither of the former features can be conclusive as to the forensic relevance of the case. For example, the extreme acidity of the soil can explain the extensive post-mortem changes even in a modern forensic case and a clandestine grave is equally likely to include a skeleton which may seem laid down as in a ritual, simply because the cadaver was laid on its back. Lack of odour and greasiness also cannot eliminate completely the possibility of a forensically relevant finding. In addition, the fact that the grave was shallow, that no historic or prehistoric artefacts were found in association with the skeleton, and that the grave was not included within an archaeological cemetery, either historic or prehistoric, raise the possibility of a modern case, albeit not necessarily a very recent one. Perhaps the most indicative evidence might have been the enamel hypoplasias, whose severity is relatively rare in developed countries and possibly more suggestive of an archaeological case.

The severe linear hypoplasias on the anterior teeth led to the possibility that the individual might be of some antiquity, but this was not indisputable and confirmation from radiocarbon analysis was required. In an attempt to unravel the antiquity or modernity of the remains, a 200 g sample of trabecular and cortical bone from the right femur was submitted to the Radiocarbon Laboratory at the *Instituto Tecnológico e Nuclear* (Sacavém, Portugal) for radiocarbon analysis using the liquid scintillation technique. The sample was first cleaned by manually removing foreign material. The following step was to grind the bone using a hammer mill in order for an easier extraction of the collagen still kept in the bone. The Longin method[13] was used for the collagen extraction as gelatine. After the gelatine has been dried it was burnt in an oxygen atmosphere and followed by a benzene synthesis. The sample was measured using the liquid scintillation technique. The radiocarbon age content was calculated in accordance with the definitions recommended by Stuiver and Polach[14] and Reimer.[15]

The results ($F^{14}C = 0.9789 \pm 0.0044$; $\Delta^{14}C = -28.1 \pm 4.4‰$; pmC = 97.19 ± 0.44% Modern) show that the bone radiocarbon content in ^{14}C values is below the 1950 level. Consequently, the individual most certainly died before the mid-1950s and a conventional radiocarbon date can be obtained from the radiocarbon content - Sac-2554 170 ± 35 BP - which can be converted to the following calendar AD time intervals (2 σ) and respective probabilities in brackets: 1656–1706 (0.190562), 1720–1819 (0.505048), 1823–1825 (0.002329), 1832–1883 (0.112652), and 1914–1953 (0.189408). These values point to death as having occurred most likely during the 18th or 19th century (calendar date intervals with greater probability) and substantiate some observations done during the anthropological examination, particularly the presence of enamel hypoplasias, which raised some suspection as to the non contemporanity of the remains. It is important to note that in spite of using a cortical (and trabecular) bone for the analysis, the individual was a young female (age at death 16–24 years), which means that the problem of radiocarbon turnover rate for the bone collagen is minimized,[3,8] as the values of $F^{14}C$, $\Delta^{14}C$ and pmC clearly correspond to pre-bomb values (see, for instance, Ubelaker and Buchholz,[6]).

4. Conclusion

In the case reported here, available evidence from the field and collected during the post-mortem examination did not allow conclusive statements about the forensic significance of the human remains. Due to absence of clear evidence pointing to an historic or modern clandestine grave, confirmation of its antiquity was required. This report demonstrates that radiocarbon analysis of human bone can be useful in clarifying the forensic relevance of human remains, which was ruled out in this case. Radiocarbon analysis provides an important means to estimate time since death when remains are completely skeletonised and the post-mortem interval is likely to be long. The best approximation of time since death is critical to prompt a criminal investigation in order to unravel the circunstances of death.

Although radiocarbon analysis confirmed that the finding is historic, it is, nonetheless, peculiar that a full skeleton was discovered in such unusual circumstances, particularly since it was not found within the context of an archaeological cemetery, either historic or contemporary. During the Early Modern ages, up until the Late Modern age, burials could only have taken place in sacred ground, such as near or inside churches and other religious buildings. Later, during the 19th century, public cemeteries were settled outside the limits of most urban centres, in order to remove interments from religious buildings for sanitary reasons.[16] The isolated finding of a single unmarked grave of this time period is strongly suggestive of a clandestine grave, where a criminal death

may have been involved or not. Even if the findings have no strictly forensic relevance and will not trigger a criminal investigation, a case such as this can add considerably to the accumulated knowledge of forensic anthropology related cases.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethical approval

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